Study and Optimal Selection of the Hydro Turbine for a SHP Plant

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Abstract— Developing a the small hydropower site is not a simple task. There are many aspects which have to be taken into contemplation, layer many disciplines ranging from business, engineering, financial, legal and organization. These all will be required at the dissimilar development stages from, first choosing a site until the plant goes into operation. As the small hydropower site are not well-known as standardized. Every site has different site parameters. It is consequently cost for growth of these sites will differ from site to site. as of non-standardization of apparatus of a SHP, cost becomes a important issue. Keeping this in view, the close by study has been carried out for optimal selection for a hydro turbine based on optimal cost of the plant. in observation of a typical dam toe site having site requirement as head of 20 m and capacity (power) 10000 KW It has been establish that use of propeller tubular turbine has contributed minimum cost of plant; therefore for the plant the turbine has been suggested.

Key words: SHP, Hydropower, Head and Capacity

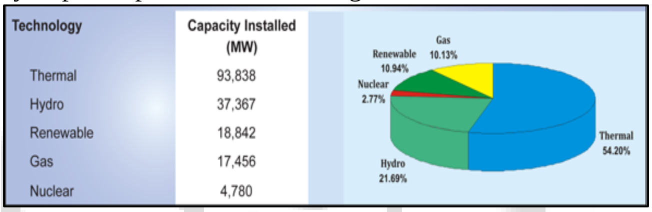
I. Introduction

The hydropower is a renewable, non-polluting and environmentally compassionate source of the energy. It is conceivably the oldest renewable energy technique known to the mankind for mechanical energy conversion as well as electricity generation. Hydropower represents use of water resources towards inflation free energy due to nonexistence of fuel cost with adult technology characterized by highest prime moving efficiency and spectacular operational flexibility.

The hydropower contributes around 22% of the World electricity supply generated from about 7, 50,000 MW of installed capacity and in various countries, it is the central source of power generation e.g. Norway, Brazil, Switzerland and Sweden . Power generating total installed capacity in the India is of 1, 72,283 MW, which includes 37, 367 MW from hydro. Although the hydroelectric projects being recognized as the most profitable and preferred source of electricity, the share of hydropower has been declining since 1963 in India. The hydropower share declined from 50% in 1963 to about 26% in 2005. For grid immovability the ideal hydro-thermal mix ratio is 40:60. It is therefore necessary to correct the hydro-thermal mix to meet the grid necessities and peak power shortage.

The Government of India has announce in August, 1998 Policy on the hydro Power Development, followed of 50,000 MW hydro-electric initiatives in May, 2003. About 70% of the population in India lives in the rural areas. The rural energy circumstance is characterized by insufficient, unfortunate and unreliable supply of energy services. Realizing the fact that small hydropower projects can provide a solution for the energy problem in the rural areas. remote and hilly areas where expansion of grid system is comparatively extravagant and also along the canal systems having sufficient drops, promoting small and mini Hydro projects is one of the objectives of the procedure on the Hydro Power Development in India. In addition, 56 number of pumped storage projects have also been recognized with probable installed capacity of 94,000 MW in the additions to this hydro-potential from small, mini& micro schemes has been predictable as 15000 MW. Thus is endowed with hydro-potential of about 2, 50,000 MW in the India.

Capital speculation of hydro if half that of thermal and considering the infrastructural costs and auxiliary factors in the India. The average cost of hydro power generation is one 3rd to one 4th of thermal. The category of hydropower potential in India is given in Table 1.



Technology	Capacity Installed (MW)
Thermal	93,838
Hydro	37,367
Renewable	18,842
Gas	17,456
Nuclear	4,780

Fig. 1: Break up of Installed power capacity in MW in India as on 31.1.2011

II. The small hydro power programme in India

The Small hydro Power (SHP) Programme is one of the power areas of power generation from renewable in the Ministry of New and Renewable Energy. It has been recognized that small hydropower projects can play a critical role in civilizing the overall energy scenario of the country and in particular for remote and unapproachable areas. The Ministry is encouraging development of small hydro projects both in the public as well as private sector. Equal concentration is being paid to grid-interactive and decentralized projects.

State	Potential (MW)	Project install (MW)	Project under implementation (MW)
Andhra Pradesh	560.18	189.83	61.75
Arunachal Pradesh	1,328.68	78.835	38.71
Assam	238.69	27.11	15
Bihar	213.25	58.3	36.31
Chattisgarh	993.11	19.05	1.2
Goa	6.5	0.05	-
Gujrat	196.97	12.6	-
Haryana	110.05	70.1	3.4
Himachal Pradesh	2,267.81	37.385	132.2
J & k	1,417.8	129.33	5.91
Jharkhand	208.95	4.05	34.85
Karnataka	747.59	725.05	107.5
Kerala	704.1	136.87	23.8

Madhya Pradesh	803.64	86.16	19.9
Maharashtra	732.63	263.825	51.7
Manipur	109.13	5.45	2.75
Meghalaya	229.8	31.03	1.7

Table 1: shows state wise SHP capacity in India

III. About the Small Hydropower

The Small hydro power (SHP) is one of the mainly common renewable, economic, non-consumptive, environmentally, non-radioactive, and non-polluting benign sources of energy. In the India has a century old history of hydropower and the beginning was from the small hydro.

Overall potential	15,000 MW
Identified potential	14294.24 MW (5403 sites)
Installed capacity	2045.61MW
Under construction	668.86 MW (225 projects)
Capacity addition during 2002-2007	Over 500 MW
Target capacity addition – 11th Plan (2007-2012)	1400 MW

Table 2: Small Hydro (Up To 25mw) Scenes

IV. Literature Review

Hosseinia et al. [20] presented a method to calculate the annual energy by developing program using Excel software. This program analyzes and estimates the most important economic indices of a small hydro power plant using the sensitivity analysis method.

Singal and Saini [6] attempted to determine the correlations for the cost of different components of canal dam toe based small hydro power schemes. The cost based on the developed correlations, having different head and capacity, has been compared with the available cost data of the existing hydropower stations.

Montanari [18] presented an original method for finding the most economically advantageous choice for the installation of micro hydroelectric plants.

Forouzbakhsh et al. [2] reviewed the structure of BOT contracts and through an economic evaluation based on different percentage of investments of private sector in providing the expenses of small and medium hydro-power plants

Voros et al. [12] analyzed the problem of designing small hydroelectric plants and addressed in terms of maximizing the economic benefits of the investment. An appropriate empirical model describing hydro turbine efficiency was developed

Date and Akbarzadeh [4] showed the performance characteristics of a simple reaction hydro turbine for power generation. Using principles of conservation of mass, momentum and energy, the governing equations have been identified for an ideal case of no frictional losses.

V. Civil Works Components

These components include diversion works, canals, surge tanks, penstocks, spillway & head race layouts etc. the majority of the small hydro schemes are run-of-river diversion schemes. In selecting of the layout and types of civil component, due consideration should be given to the constraint for reliability and local standard construction. The small hydro schemes utilizing large dams for seasonal river regulations are generally repellent because the civil works for these are very luxurious unless the scheme is at an existing dam or part of a larger versatile scheme.

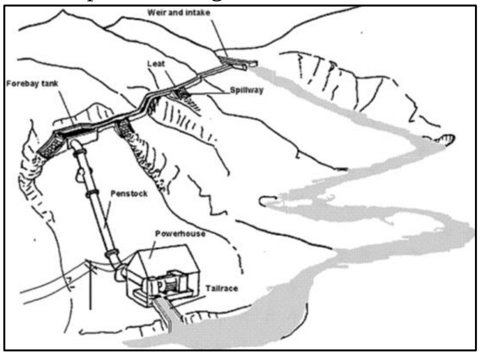


Fig. 2: Different Components of the Small Hydro Power Plant

A. Intakes

The side, front and bottom intakes are mostly used for the small hydro schemes. The side and front intakes are suitable for the river with sand and silt bed load. The bottom one is more suitable for mountain streams. The demanders may be provided to reduce the balanced load so as to reduce bear on turbines and blocking of penstock or head race.

B. Dam

The Dams and weirs are mainly intended to divert the river flow into the water conveyance system leading to the power house. Dams also create additional head and provide storage capacity. The choice of dam type depends largely on local topographical and geotechnical situation.

C. Penstock

The penstocks made of mild steel represent major expenses and hence to minimize its length, head race might be used. A stop valve must be provided at the way in to avoid the problems of water hammer. The optimum size of head race may be obtained by an scrutiny of construction and annual cost of the energy lost due to friction in the head race over the monetary life span of the project.

D. Power House

Power house is the houses of the turbine, generator and control panels. It should be as simple as potential. The significant parameters upsetting the cost of power house i.e. super structures and substructures can be connected to number and capacity of turbine and generators. The separate auxiliary building for office and workshop should be constructed if it required.

E. Tail Race Channel

After the generation of electricity in the power house for discharging water either a tail race channel or a tail race tunnel will be required. The design of tail race channel will follow the same morality as of any hydraulic channel. The tailrace channel of insufficient capacity and sufficient slope is provided to clear the discharges from the machines rapidly.

VI. ELECTRO-MECHANICAL COMPONENTS

This is generally include turbine, generator and control equipments .consume the major part of the total cost of the project and affect the output level of the project.

A. *Turbine*

The selection of the hydro turbine for the small hydro depends on the head and discharge available. A low head installation requires flow of water typically in plains on canal falls and cross drainage works while high head would typically require low discharge as in hilly areas.

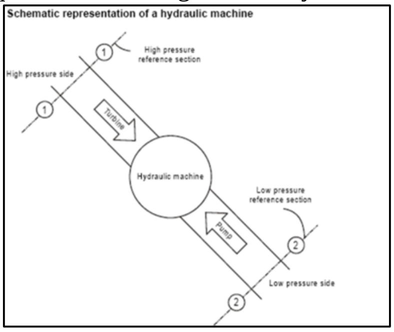


Fig. 3: Schematic representation of a hydraulic machine [26]

VII. ANALYSIS METHODOLOGY

The cost of the thesis depends on location, construction period and variation in cost of materials, availability of construction equipment and variation in labour cost. The total thesis cost includes cost of civil works, cost of other miscellaneous items cost of electromechanical equipment

In the present thesis a typical site having measurement as head of 20m and capacity 10000 kW has been considered and overall cost of the schemes for different turbines has been analysed.

VIII. COST ESTIMATION

A. *Case 1 Cost of SHP Plant When the Tubular Propeller Turbine Use*

Cost calculation of various components of the SHP plant when tubular propeller turbine in use has been calculated as complete in Chapter and results data are tabulating as shown in the table 3.

Types of Cost	**Cost Per Kw**	**Total Cost (Rs)**
Cost of the Intake (C_1)	1690	16977780
Cost of Penstock(C_2)	730	7392000
Cost of the Power House(C_3)	8730	87345760
Cost of the Tailrace Channel(C_4)	130	1360970
Cost of the Tubular Propeller Turbine(C_5)	5330	53378980
Cost of Generator & Excitation System (C_6)	7630	76340480
Cost of Auxiliary(C_7)	3500	35081350
Cost of Transformer & Switchyard System (C_8)	1910	19124170
Total Cost of Civil Work ($C_c=C_1+C_2+C_3+C_4$)	11300	113076540
Total Cost of Electromechanical Work ($C_{e\&M}=C_5+C_6+C_7+C_8$)	18390	183925000

Table 3: Shows the various cost calculations for assumed site specification (for tubular propeller turbine)

B. *Case 2 Cost of SHP Plant When the Tubular Kaplan Turbine is Use*

Calculation Cost of the various components of the SHP plant when tubular Kaplan turbine in use .calculated as done in the Chapter and results data are tabulated as shown in the Table 4.

Types of Cost	**Cost Per Kw**	**Total Cost(Rs)**
Cost of the Intake(C_1)	1690	16977780
Cost of Penstock(C_2)	730	7392000
Cost of the Powerhouse(C_3)	9350	93572510
Cost of the Tailrace Channel(C_4)	130	1360970
Cost of the Tubular Kaplan (C_5)	6880	68841450
Cost of Generator & Excitation System (C_6)	7890	78961850
Cost of Auxiliary(C_7)	4000	39992350
Cost of Transformer & Switchyard (C_8)	1910	19124170
Cost of Civil the Work ($C_c=C_1+C_2+C_3+C_4$)	11930	119303280
Cost of the Electromechanical Work($C_{e\&M}=C_5+C_6+C_7+C_8$)	20690	206919830

Table 4: shows the various cost calculations for assumed site specification (for tubular Kaplan turbine)

C. *Case 3 Cost of SHP Plant When the Vertical Semi-Kaplan Turbine is Use*

Calculation the Cost of the various components of the SHP plant .when vertical semi-Kaplan turbine in use has been calculated as done in Chapter-3 and results data are tabulated as shown in the Table 5.

Types of Cost	**Cost Per Kw**	**Total Cost (Rs)**
Cost of the Intake(C_1)	1690	16977780
Cost of Penstock(C_2)	730	7392000
Cost of the Powerhouse(C_3)	8000	80074950
Cost of the Tailrace Channel (C_4)	130	1360970
Cost of the Vertical Semi-Kaplan Turbine(C_5)	6200	62013890
Cost of the Generator & Excitation System(C_6)	8240	82400140
Cost of Auxiliary(C_7)	4090	40919850
Cost of Transformer & Switchyard(C_8)	1910	19124170
Cost of the Civil Work ($C_c=C_1+C_2+C_3+C_4$)	10580	105805730
Cost of the Electromechanical Work ($C_{e\&M}=C_5+C_6+C_7+C_8$)	20440	204458070

Table 5: Shows the various cost calculations for assumed site specification (for vertical semi-Kaplan turbine)

IX. CALCULATION OF MISCELLANEOUS COST

Miscellaneous cost of the any SHP plant depends upon the types of scheme and types of turbine etc. precisely it is assumed that the miscellaneous cost is 0.13 times of sum of cost of civil work cost and electromechanical cost.

$$C_{misc.} = 0.13(C_C + C_{e\&m}) \quad (4.1)$$

Where C_{misc} =miscellaneous cost per kW

By using Eqn. (4.1) for calculated cost of miscellaneous items for different turbines and results are tabulated as shown in Table 6.

Types turbines	Head	Power (kW)	C_{misc} (Rs)
Tubular propeller turbine	20	10000	3860
Tubular Kaplan turbine	20	10000	4240
vertical semi-Kaplan turbine	20	10000	4030

Table 6: Different Turbines and Results

X. TOTAL COST ESTIMATION

Total cost will be sum of cost of civil works, electromechanical equipment and miscellaneous items and is given as

$$C_T = C_c + C_{e\&m} + C_{misc.} \qquad (4.2)$$

By using Eqn. (4.2) total cost for different turbines has been calculated and results are tabulated as shown in the Table 7.

Types of turbine	Head (m)	Power (KW)	Overall Cost per KW of plant	Total cost of plant (Rs)
Tubular propeller turbine	20	10000	33561.17430	335611743.0
Vertical semi-Kaplan	20	10000	35059.67520	350596752.0
Tubular Kaplan	20	10000	36863.21240	368632124.0

Table 7: Overall cost of the plant for different turbines

From Table as result it is found that the variation in cost of the plant from turbine to turbine. The variation in the total cost of low head dam toe based SHP scheme is shown in the Fig.

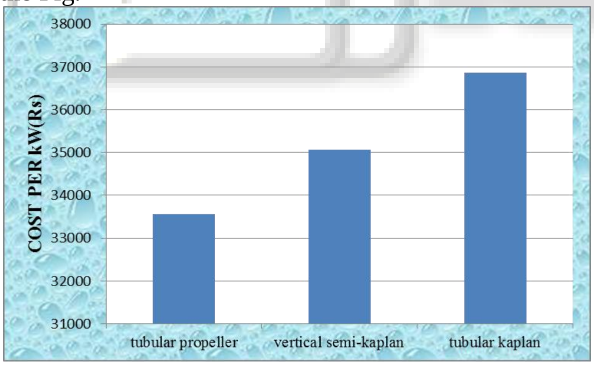


Fig. 2: comparison in cost per kW of the plant

The Above chart is plotted against different turbine versus cost per kW shows in figure that the overall cost of the plant is minimum when tubular propeller turbine use in compare to tubular Kaplan and vertical semi-Kaplan. And Hence on the basis of cost the plant is more economical when propeller tubular turbine is use.

XI. CONCLUSION

For the typical dam toe site having head 20m and capacity 10000kW cost of dissimilar components of civil works and electro-mechanical equipments for low head dam toe SHP using dissimilar turbines has been calculated and optimal selection of hydro turbine has been suggested. From the study it has been found that as:-

- For the considered site cost of SHP plant per kW (in Rs) is 33560,35058 and 36864when tubular propeller turbine, vertical semi-Kaplan and tubular Kaplan turbine are used respectively.
- Cost of such a considered distinctive low head dam toe based SHP would be minimum when propeller tubular turbine is in used.
- Cost of such a considered distinctive low head dam toe based SHP would be maximum when tubular Kaplan turbine is used.

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